Original Article

The Incidence and Management of Moderate to Severe Head Injury

A Retrospective Analysis of Data From the Trauma Register of the German Trauma Society

Marc Maegele, Rolf Lefering, Oliver Sakowitz, Marcel A. Kopp, Jan M. Schwab, Wolf-Ingo Steudel, Andreas Unterberg, Reinhard Hoffmann, Eberhard Uhl, Ingo Marzi

Summary

Background: The comprehensive expansion of the Trauma Register of the German Trauma Society (*Deutsche Gesellschaft für Unfallchirurgie*; TR-DGU) now enables, for the first time, studies on traumatic brain injury (TBI) with special attention to care processes, clinical course, and outcomes of treatment on discharge or transfer from the acute-care hospital.

Methods: Retrospective analysis of patients documented in the TR-DGU in the period 2013–2017 who had moderate to severe head injury as defined by the Abbreviated Injury Scale (AIS).

Results: In the period 2013–2017, 41 101 patients with moderate to severe TBI were treated in TR-DGU–associated hospitals in Germany ($n = 605$ hospitals), corresponding to 8220 cases per year and thus to a population-wide incidence of 10.1 cases per 100 000 persons per year. TBI was present as an isolated injury in 39.1% of cases. The mean age of the patients was 60 years (median; range 0–104 years), and the male-to-female ratio was 2:1. 97.5% of the patients had blunt trauma. Falls from a low height were the most common cause of TBI (38.7%). 43.6% of the patients were intubated before arriving at the hospital, and more than 95% underwent cranial tomographic imaging within 22 minutes of arrival (standard deviation [SD] = 17 minutes). 18.4% underwent an emergency neurosurgical procedure. The in-hospital mortality was 23.5%, corresponding to a population-wide mortality from TBI of 2.4 per 100 000 persons per year. More than half of the patients recovered well or with only mild disability; 14.9% had persistent severe disability or remained in a vegetative state.

Conclusion: Putting these figures in the appropriate international context requires the acquisition of comparable data in multiple countries and is the main task of international TBI consortia.

Cite this as:

Maegele M, Lefering R, Sakowitz O, Kopp MA, Schwab JM, Steudel WI, Unterberg A, Hoffmann R, Uhl E, Marzi I: The incidence and management of moderate to severe head injury—a retrospective analysis of data from the Trauma Register of the German Trauma Society. *Dtsch Arztebl Int* 2019; 116: 167–73. DOI: 10.3238/arztebl.2019.0167

Traumatic brain injury (TBI) remains one of the major medical and socioeconomic challenges of our time (1–4). In 2016, 419 507 patients were hospitalized for TBI of all grades of severity (ICD-10 S00–S09: injuries to the head) in Germany alone (5). TBI is among the leading causes of death and permanent disability in persons aged 29 to 45 (3, 6, 7). Recent observations and data provided in the regular health reports of the German federal government reflect current patterns of demographic change, indicating a shifting epidemiological reality in which TBI is increasingly seen in elderly persons who fall at home (5, 7–10).

Data on the epidemiology of TBI, the care of patients with TBI, and their clinical course after the injury remain highly variable and unsatisfactory. This is due to a continuing lack of uniform definitions, along with heterogeneity of data sources, documentation, inclusion and exclusion criteria, study methods, and reporting practices (3–20). Yet robust data are essential for the estimation, assessment, and quantification of the extent of the problem for purposes of health policy; for the

planning, development, and implementation of preventive measures; for an improved understanding of patients' needs; and for the allocation of resources. The data available until now on TBI in Germany—which are more than a decade and a half old—are shown in *Table 1*. The most reliable figures are those of the Hanover-Münster Cohort Study, which was carried out in a single year (03/2000–03/2001) in two model regions (the city of Hanover with its administrative district [*Landkreis*], and the city of Münster with the surrounding catchment area) and included a total of 6873 patients (15). A rough extrapolation at that time yielded an estimate of 273 000 TBI cases in Germany per year, generating costs of ca. €2.5 billion (15). A population-based study (01/1999–12/1999) with data from 130 000 protocols of emergency medical assistance in a metropolitan region in the western part of Germany (1 million inhabitants) focused on severe TBI stratified by Glasgow Coma Scale (GCS) ≤ 8 at the site of the accident and/or the Abbreviated Injury Scale for the body region “head” (AIS_{head}) and tomographic imaging.

This study documented an incidence of 7.3 cases per 100 000 inhabitants, with an overall mortality of 45.8% (18).

From 1993 onward, data on the acute care of severely injured patients with or without TBI in Germany have been entered into the Trauma Register of the German Trauma Society (*Deutsche Gesellschaft für Unfallchirurgie*; TR-DGU) (21). With the later introduction of the DGU Trauma Network, data acquisition for quality assurance was comprehensively expanded: starting in 2013, more than 30 000 trauma patients per year have been registered in the approximately 600 trauma-certified hospitals belonging to the network. This expansion now enables the performance of studies on TBI covering all of Germany, based on the TR-DGU, with special attention to care processes and treatment outcomes. The findings are compared with the data that were available for Germany until now.

Methods

DGU Trauma Register

The TR-DGU was founded in 1993 with the objective of documenting data on severely injured patients in standardized fashion in a multicenter database (21). The data are documented prospectively by the participating hospitals in four phases of acute care: the prehospital phase, emergency-room admission and surgery, intensive care, and discharge. They include demographic data and information on the pattern of injury, comorbidities, management in the prehospital phase and in the hospital, the clinical course during intensive care, the initial laboratory findings, transfusion data, and the treatment outcome on discharge or transfer from the acute-care hospital. The inclusion criterion is hospital admission through the emergency room with subsequent monitoring in an intensive or intermediate care unit (ICU/IMC), or else arrival in the emergency room with present vital signs and then death before admission to the ICU or IMC. The infrastructure for documentation and data management and analysis was provided by the Trauma Surgery Academy (*Akademie*

der Unfallchirurgie GmbH, AUC), and the leading scientific role was taken by the DGU section on emergency and intensive-care medicine and severe trauma care (*Notfall, Intensivmedizin und Schwerverletztenversorgung*, NIS). Participation is voluntary; the submission of at least one reduced basic data set (quality management questionnaire) is mandatory for centers belonging to the DGU Trauma Network (21). This publication is in conformity with the TR-DGU publication guideline (TR-DGU ID 2016–007).

Patients

This study concerns all patients in Germany who were entered into the TR-DGU in the period 2013–2017 and who had a relevant head injury ($AIS_{head} \geq 3$) on admission to a participating acute-care hospital. The AIS was introduced in the late 1960s, with subsequent revisions, as a simplified, expert-based anatomical scale for the severity of bodily injuries, including TBI (22, 23). The AIS classification awards 1 to 6 points for injuries in each individual part of the body—including the head (AIS_{head} / group 1)—on the basis of the probability of survival. An injury with severity 1 on the AIS scale is never fatal, while an injury with severity 6 is almost certainly so (22). In order to avoid duplication of patients, data on TBI patients who were transferred to a second acute-care hospital within 48 hours are taken only from the second hospital, as this data set contains the treatment outcome at the time of discharge or transfer out of acute care.

Statistics

Metrics and case numbers are given as means, standard deviations, and medians, and categorical quantities in percent. The cases are derived from an overall German population of 81.6 million people (as reported in the 2011 census). The incidence of hospitalization for moderate to severe TBI in Germany is reported as a figure per 100 000 persons per year. The overall incidence is estimated to be 35% higher because of under-registration and deaths before hospital admission (18). Because of the high case numbers, no confidence intervals were calculated; the frequencies reported are precise to within 1%.

Department of Orthopaedic Surgery, Trauma Surgery, and Sports Medicine, Cologne Merheim Medical Center, Witten/Herdecke University, Cologne: Prof. Dr. med. Marc Maegele

Institute for Research in Operative Medicine (IFOM), Witten/Herdecke University, Cologne: Prof. Dr. med. Marc Maegele, Prof. Dr. rer. medic. Rolf Lefering

Neurosurgical Center Ludwigsburg-Heilbronn, RKH Klinikum Ludwigsburg, Academic Teaching Hospital of Heidelberg University, Ludwigsburg: Prof. Dr. med. Oliver Sakowitz

Department of Neurology with Experimental Neurology, Charité-Universitätsmedizin Berlin and Berlin Institute of Health (QUEST), BIH Center for Transforming Biomedical Research, Berlin: Dr. med. Marcel A. Kopp, Prof. Dr. med. Dr. rer. nat. Jan M. Schwab

Department of Neurology and Neuroscience, Director Spinal Cord Injury Division, Ohio State University, Columbus (Ohio) USA: Prof. Dr. med. Dr. rer. nat. Jan M. Schwab

Saarland University Medical Center, Homburg/Saar: Prof. Dr. med. Wolf-Ingo Steudel

Department of Neurosurgery, Heidelberg University Hospital, Heidelberg: Prof. Dr. med. Andreas Unterberg

BG Trauma Center Frankfurt/Main: Prof. Dr. med. Reinhard Hoffmann

Department of Neurosurgery Gießen, University Gießen-Marburg Gießen: Prof. Dr. med. Eberhard Uhl

Department of Trauma-, Hand- and Reconstructive Surgery, J.W. Goethe University Hospital, Frankfurt/Main: Prof. Dr. med. Ingo Marzi

Results

Incidence

In the period 2013–2017, a total of 41 101 patients with moderate to severe SHT were treated in 605 TR-DGU associated hospitals and documented in the TR-DGU (QM questionnaire: n = 18 494):

- Care level 1/interregional trauma center: 114 hospitals, 29 879 patients
- Care level 2/regional trauma center: 209 hospitals, 9289 patients
- Care level 3/local trauma center: 285 hospitals, 1933 patients.

This corresponds to 8220 cases per year (range, 7456–8565 cases) with a raw incidence of 10.1 cases per 100,000 persons per year of hospitalization for moderate to severe TBI in Germany. Adding 35% to this figure to account for underreporting and deaths before hospital admission yields an overall incidence estimate of 13.6 cases per 100,000 persons per year.

Description of the patient collective

The median patient age was 60 years (range, 0–104 years), and the male-to-female ratio was 2 : 1 (27 796 male to 13 305 female). The most common mechanism of injury was blunt trauma (97.5%). *Figure 1* shows incidence as a function of age for each sex, revealing a trimodal distribution; *Figure 2* shows the increasing incidence of TBI with age. Falls from a low height were the most common cause (38.7%; n = 15 502; *Figure 3*). Men sustained moderate to severe TBI much more commonly than women, in a ratio of 2:1, regardless of the type of accident (motor vehicle accident, pedestrian accident, or fall). The median age of persons injured in motor vehicle accidents was 36 for car accidents and 40 for motorcycle accidents; the median age of persons injured in falls from a height less than 3 meters was 75. Nearly half of the patients (43.6%; n = 14 936) were intubated and ventilated before reaching the hospital. Among patients who arrived unconscious (GCS ≤ 8), the intubation rate was 85.1% (n = 11 211). Among patients with GCS ≤ 8, the distribution of AIS_{head} scores was: 3 points, 25.9% (n = 3414); 4 points, 27.4% (n = 3611); 5 points, 45.3% (n = 5983); and 6 points, 1.4% (n = 188).

Patterns of head injury and accompanying injuries

TBI was documented as an isolated injury in 39.1% of the patients (n = 16 083) (i.e., AIS scores of ≥ 3 for the head only, and ≤ 1 for all other regions of the body). The distribution of AIS_{head} scores is shown in *Figure 4*, while the patterns of injury, types of intracranial bleed, and accompanying injuries by body region are shown in *Table 2*. Fractures of the calvaria or skull base were documented in half of the patients, and one patient in four had brain contusions. The most common type of intracranial bleed was a subdural hematoma (SDH), which was found in 47.5% of the patients. TBI was accompanied by relevant injuries in other body regions in 60.8% of the patients (n = 24 969). One patient in four (26.2%; n = 10 762) had laboratory abnormalities indi-

TABLE 1

Overview of epidemiologic studies of TBI in the Federal Republic of Germany to date, including the findings of the current study

Study (Reference number)	Period	Source data	TBI definition	TBI severity	Number of patients	Mean age of patients	Sex: m (%); m:f	Cause (%)	Incidence per 100 000 persons per year	Mortality per 100 000 persons per year	Case Fatality Rate
Steudel et al. (16)	1972–1998	Hospital admission register, register of deaths	ICD-9 and -10	All severities; mild TBI: 72%	297 029	ND	ND	ND	337 Severe TBI: 30.5	27.20 (1972) 9.4 (1999)	2.7/100
Firsching and Woischneck (17)	1996	Death certificates, hospital discharge summaries	ICD-9	All severities; mild TBI: 73%	280 000	39 years	71% ; 2.45:1	MVA: 56 Fall: 31	350 Mild TBI: 247	11.5	ND
Maeglele et al. (18)	1990–1999	Emergency physician reports from Cologne (city), hospital records	GCS and AIS _{head} (CT)	Severe TBI	731	40.3 years	73% ; 2.7:1	MVA: 55.3 Fall: 35	Severe TBI: 7.3	3.3	45.8/100
Rickels et al. (15)	2000–2001	Hospital records, model regions Hanover and Münster	GCS and ICD-10	All severities stratified by GCS Mild TBI: 90.9% Moderate TBI: 3.9% Severe TBI: 5.2%	6873	ND	58.4% ; 1.4:1	Fall: 52.5 MVA: 26.3	332 Mild TBI: 302 Moderate TBI: 13 Severe TBI: 17 Hanover reg.: 375 Münster reg.: 268	3.3	1/100 Mild TBI: 0.1/100 Moderate TBI: 4.8/100 Severe TBI: 21.3/100
Current study	2013–2017	DGU Trauma Register	AIS _{head}	Moderate to severe	41 101	60 years (median)	2:1	Fall: 38.7 MVA: 31.8	10.1 (13.6*)	2.4*2 (3.3*3)	23.5*2/100

*1 after taking account of 10% underregistration and of deaths from TBI before hospital admission; *2 in-hospital mortality; *3 after taking account of deaths from TBI before hospital admission.

AIS, Abbreviated Injury Scale; CT, computed tomography; DGU, German Trauma Society (*Deutsche Gesellschaft für Unfallchirurgie*); f, female; GCS, Glasgow Coma Scale; ICD, International Classification of Disease; m, male; MVA, motor vehicle accident; ND, not documented; reg., region; TBI, traumatic brain injury

FIGURE 1

Trimodal age distribution of moderate to severe traumatic brain injury in men and women:

- First peak: marked difference in incidence between the sexes, starting at puberty and rising until age 18 (driver's license); "testosterone effect" > "young risk-takers"; male > female)
- Second peak: mid-fifties ("older risk-takers"; work accidents)
- Third peak: late seventies (incidence in the two sexes is now more nearly equal; mainly falls)

FIGURE 2

Increasing annual incidence of moderate to severe traumatic brain injury with age on the basis of case data from the Trauma Register of the German Trauma Society (TR-DGU)

cating dysfunction of the blood coagulation system at the time of admission (International Normalized Ratio [INR] >1.2, Quick value <70, activated partial thromboplastin time [aPTT] >40 s, or platelet count <100×10⁹/L). Likewise, one in four (25.9%; n = 10 638) had a relevant past medical history by ASA criteria (ASA 3–4).

Care

Among the primarily treated patients who were unconscious (GCS ≤ 8) on admission to the hospital, 94.4% (n = 12 455) underwent tomographic imaging of the head, as did 97.9% (n = 19 346) of those who arrived with GCS 9–15. In 3.5% of cases overall (n = 1153), no tomographic imaging was documented as part of the evaluation in the emergency room; these were the patients who

- underwent resuscitation attempts in the emergency room and died without imaging, or
- underwent emergency surgery at once because of another life-threatening condition, or
- were transferred to the intensive care unit first, and underwent tomographic imaging afterward.

The mean interval from arrival in the hospital to tomographic imaging was 22.2 minutes (standard deviation [SD]: 17.8 minutes; median [M]: 18 minutes; interquartile range [IQR_{25–75}]: 12–26 minutes). 2801 patients (18.4%) underwent an emergency neurosurgical procedure between arrival in the hospital and admission to an intensive care or intermediate care unit; these were urgent operations to reduce elevated intracranial pressure. The patients remained intubated for a mean of 5 days (SD: 9.2 days, M: 1 day; IQR_{25–75}: 0–6 days) and spent a mean of 8.9 days (SD: 11.9 days, M: 4 days, IQR_{25–75}: 1–13 days) in the intensive care unit. The mean overall length of hospital stay was 16.5 days (SD: 16.9 days, M: 12 days, IQR_{25–75}: 6–22 days). Half of the patients (51.4%; n = 10 626 [QM questionnaire]) had organ failure, and 33.6% (n = 6970 [QM questionnaire]) had multiple organ failure (MOF); 8.3% (n = 1650 [QM questionnaire]) developed sepsis over the course of their hospitalization.

Treatment outcomes on discharge or transfer from the acute-care hospital

The in-hospital mortality was 23.5% (n = 9676), corresponding to a TBI-related mortality in the general population of 2.4 deaths per 100 000 persons per year. The calculated overall mortality, including patients with TBI who died without reaching the hospital, was 3.3 deaths per 100 000 persons per year. *Figure 4* shows mortality as a function of the severity of TBI, as measured by the AIS_{head} score. One-third of the patients (36.3%; n = 14 903) were discharged home, and another third (36.8%; n = 15 120) were transferred to another hospital or to a rehabilitation facility. More than half (61.1%; n = 24 479) made a good recovery or were only mildly disabled on leaving the acute-care hospital; 14.9% (n = 5978) survived with a severe disability or in a persistent vegetative state. *Figure 5*

shows the clinical condition on discharge or transfer out of the acute-care hospital (Glasgow Outcome Scale, GOS) in relation to the severity of the initial injury.

Discussion

The incidence of hospitalization for moderate to severe traumatic brain injury in Germany was determined from data in the TR-DGU for the years 2013–2017 to be 10.1 cases per 100 000 persons per year. This figure is somewhat higher than the incidence previously reported for relevant TBI in a western German metropolitan region (18), but lower than the corresponding figure from the Hanover-Münster cohort study, in which moderate and severe TBI were stratified by GCS (15). TBI rates are known to differ between urban and rural regions (2, 3), and differences were also seen between the two model regions of the Hanover-Münster cohort study (15). The overall incidence, when cases not included in the register are taken into account, is somewhat higher, at 13.6 cases per 100 000 persons per year, but this is only an estimate. Causes for under-registration include, for example, incomplete reporting or non-reporting of some cases in participating hospitals where TBI patients do not pass through the trauma emergency room or undergo neurosurgical treatment immediately upon admission, or treatment in a hospital that does not participate in the TR-DGU. Experience suggests that such cases account for less than 10% of the overall number, in view of the comprehensive expansion of the TR-DGU by the DGU Trauma Network. Patients who died before reaching the hospital are not included in the TR-DGU. A review of emergency medical team protocols in a population-based study indicated that, in one western German metropolitan region, 28% of persons with TBI died before reaching the hospital (18). Three-quarters of all of the patients documented here were treated in interregional level 1 trauma centers, with 24-hour presence of a board-certified neurosurgeon as a criterion for certification.

It is hard to compare the present findings with the figures contained in the German federal health report of 2016, concerning a total of 419 507 cases of hospitalization with TBI (5), because the severity of those patients' head injuries was not indicated. 305 086 of the patients were hospitalized for only 1–3 days and thus presumably had mild TBI. Mild TBI was probably the most common diagnosis in the remaining 114 412 patients as well, as only 6286 deaths were reported in the entire collective (5). The present study is restricted to moderate to severe TBI requiring intensive care on admission; this is a criterion for inclusion in the TR-DGU (21).

Although the federal health reports document a steady increase in the frequency of hospitalization with TBI (5), a comparison of recent years with earlier years also reveals a declining frequency of moderate to severe TBI (17). Moreover, the findings confirm the demographic and epidemiological shift toward older, comorbid patients (3, 8, 9) with polypharmacy (3, 24, 25), in whom falls are the most common cause of injury

FIGURE 3

The distribution of causes of injury. Falls from lesser (<3 m) and greater heights (>3 m) accounted for half of all cases of moderate to severe TBI documented in the Trauma Register of the German Trauma Society (TR-DGU)

FIGURE 4

The frequency and mortality of moderate to severe traumatic brain injury as a function of the severity of injury according to the Abbreviated Injury Scale for the head (AIS_{head}). Injuries become less common, but more lethal, with increasing severity. The AIS classification assigns 1 to 6 points to injuries of each part of the body—including the head—according to the probability of survival. The following designations are used for different AIS_{head} scores: AIS = 3: serious moderate trauma; AIS = 4: severe trauma; AIS = 5: critical trauma; and AIS = 6: maximal, untreatable trauma

(3, 8–10). Motor vehicle accidents remain a major cause of severe TBI in younger persons (3, 6). Specifically in Germany, unlike in other countries, the age-distribution curve of TBI is trimodal for both sexes, with an additional peak between the ages of 44 and 60. The reason may be work accidents, which are more common in this age group.

The present study also reveals changes in the early phases of treatment, although it should be borne in mind that this study only concerns patients with moderate to severe TBI. The 86% intubation rate

TABLE 2

Pattern of injury, types of intracranial bleeding, and accompanying injuries, with severity ratings according to the Abbreviated Injury Scale for the affected body regions (AIS_{region} ≥ 2)

Injury	n (%)
Fractures of the calvaria and skull base	21 193 (51.6)
Brain contusions	9713 (23.7)
Type of intracranial bleeding	
Subdural hematoma (SDH)	19 514 (47.5)
Subarachnoid hemorrhage (SAH)	14 645 (35.6)
Intracerebral hemorrhage (ICH)	7908 (19.2)
Epidural hematoma (EDH)	3959 (9.6)
Combined bleeding types	12 305 (38.9)
Associated injuries, by number of affected body regions	
TBI + 1 additional body region with AIS _{region} ≥ 2	11 059 (26.9)
TBI + 2 additional body regions with AIS _{region} ≥ 2	8223 (20)
TBI + 3 or more additional body regions with AIS _{region} ≥ 2	5687 (13.9)
Associated injuries (AIS_{region} ≥ 2) by region	
Chest	14 338 (34.9)
Upper limbs	9551 (23.2)
Spine	9117 (22.2)
Face	7513 (18.3)
Lower extremities	5529 (13.5)
Pelvis	4302 (10.5)
Abdomen	3623 (8.8)

among patients found unconscious (GCS ≤ 8) at the scene of the injury was markedly higher than that in the Hanover-Münster cohort study, in which only half of the unconscious patients were intubated. It is recommended in the German S3 guideline on polytrauma and the care of the severely injured (AWMF-Nr. 012/019; [26]) that patients with severe TBI and GCS ≤ 8 should be intubated and ventilated for emergency general anesthesia in the pre-hospital phase (grade B recommendation). Nearly all patients in the present study underwent tomographic imaging of the head, at a median time of 22 minutes after arrival in the hospital. In comparison with the Hanover-Münster cohort study, three times as many emergency neurosurgical procedures were performed between admission to the emergency room and transfer to intensive or intermediate care. Once again, it must be borne in mind that the present study was restricted to patients with moderate to severe TBI.

The reported mortality and treatment outcomes pertain to patients with moderate to severe TBI, either

FIGURE 5

Treatment outcome and clinical condition on discharge or transfer from the acute care hospital, according to the Glasgow Outcome Scale (GOS), in consideration of the severity of the initial injury according to the Abbreviated Injury Scale for the head (AIS_{head}). PVS, persistent vegetative state; GOS scores in parentheses in the figure

as an isolated injury or combined with other injuries, in the interval from admission to discharge or transfer from the acute-care hospital. The TR-DGU is an acute-care register containing data only up to the time of discharge or transfer from the acute-care hospital. These data, therefore, do not enable any long-term or follow-up investigation. More than one-third of the patients were transferred to another hospital or rehabilitation facility, and another third were discharged home. In the Hanover-Münster cohort study, which was stratified by GCS, half of all patients with moderate (GCS 8–13) or severe TBI (GCS <8) underwent either early in-hospital rehabilitation or subsequent rehabilitation in another facility (15). According to the TR-DGU data examined in the present study, more than half of all patients made a good recovery from their injury, as measured by the GOS. The published data on treatment outcomes do not permit any reliable comparisons, as they are inconsistent because of the problems already mentioned above with respect to the quality and extent of reporting (10).

Standardized data acquisition methods are a prerequisite to valid comparisons of TBI data across countries and are thus an important task for international TBI consortia (27). The German Trauma Society (DGU), in collaboration with the German Society for Neurosurgery (*Deutsche Gesellschaft für Neurochirurgie*, DGNC), is now working on an

extension of the TR-DGU with an additional TBI-specific module that is harmonized with international data acquisition systems and registers and will also include long-term follow-up data. The programming work by the AUC has been completed, and the pilot phase has begun.

Acknowledgement

The creation of a nationwide TBI cohort in synchrony with the TR-DGU and international TBI consortia received important initial financial support from the Kuratorium ZNS-Hannelore Kohl-Stiftung and from the German Social Accident Insurance (*Deutsche Gesetzliche Unfallversicherung, DGUV*).

Conflict of interest statement

Prof. Unterberg has received funding from Vasopharm and CENTER-TBI for carrying out clinical trials.

Prof. Lefering's institution has a service agreement with AUC GmbH, which owns the register. The agreement also includes statistical assistance for the publication.

Dr. Kopp has received funding from the Hannelore Kohl-Stiftung and from the German Social Accident Insurance (DGUV) for a research project that he initiated.

Prof. Sakowitz has received support for the performance of clinical trials from CENTER-TBI.

Prof. Maegele, Prof. Marzi, Prof. Schwab, Prof. Hoffmann, Prof. Steudel, and Prof. Uhl state that they have no conflict of interest.

Manuscript received on 13 July 2018; revised version accepted on 4 January 2019.

Translated from the original German by Ethan Taub, M.D.

References

- Cole TB: Global road safety crisis remedy sought: 1.2 million killed, 50 million injured annually. *JAMA* 2004; 291: 2531–2.
- Feigin VL, Theadom A, Barker-Collo S, et al.: Incidence of traumatic brain injury in New Zealand: a population-based study. *Lancet Neurol* 2013; 12: 53–64.
- Maas AIR, Menon DK, Adelson PD, et al.: Traumatic brain injury: integrated approaches to improve prevention, clinical care, and research. *Lancet Neurol* 2017; 16: 987–1048.
- Li M, Zhao Z, Yu G, Zhang J: Epidemiology of traumatic brain injury over the world: A systematic review. *Gen Med (Los Angeles)* 2016; 4: 275.
- Gesundheitsberichterstattung des Bundes: Diagnosedaten der Krankenhäuser ab 2000/Eckdaten der vollstationären Patienten und Patientinnen für das Jahr 2016; ICD 10 S00–S09: Verletzungen des Kopfes. www.gbe-bund.de (last accessed on 22 September 2018).
- Maas AI, Stochetti N, Bullock R: Moderate and severe traumatic brain injury in adults. *Lancet Neurol* 2008; 7: 728–41.
- Rosenfeld JV, Maas AI, Bragge P, Morganti-Kossmann MC, Maneley GT, Gruen RL: Early management of severe traumatic brain injury. *Lancet* 2012; 380: 1088–98.
- Roozenbeck B, Maas AI, Menon DK: Changing patterns in the epidemiology of traumatic brain injury. *Nature Reviews Neurology* 2013; 9: 231–6.
- Peeters W, van den Brande R, Polinder S, et al.: Epidemiology of traumatic brain injury in Europe. *Acta Neurochir (Wien)* 2015; 157: 1683–96.
- Brazinova A, Rehorcikova V, Taylor M, et al.: Epidemiology of traumatic brain injury in Europe: a living systematic review. *J Neurotrauma* 2016; 33: 1–30.
- Langlois JA, Sattin RW: Traumatic brain injury in the United States: research and programs of the Centers for Disease Control and Prevention (CDC). *J Head Trauma Rehabil* 2005; 20: 187–8.
- Tagliaferri F, Compagnone C, Korsic M, Servadei F, Kraus J: A systematic review of brain injury epidemiology in Europe. *Acta Neurochir (Wien)* 2006; 148: 255–68.
- Rutland-Brown W, Langlois JA, Thomas KE, Xi YL: Incidence of traumatic brain injury in the United States. *J Head Trauma Rehabil* 2006; 21: 544.
- Hillier SL, Hiller JE, Metzger J: Epidemiology of traumatic brain injury in South Australia. *Brain Inj* 1997; 11: 649.

Key messages

- As determined from cases documented in the DGU Trauma Register over the period 2013–2017, the incidence of hospitalization for moderate to severe traumatic brain injury (TBI) in Germany is 10.1 per 100 000 persons per year. The overall incidence is estimated at 13.6 per 100 000 persons per year.
- Because of demographic trends, the age of patients with TBI is rising, and falls from a low height have replaced motor vehicle accidents as the most common cause.
- More than 95% of patients with moderate to severe TBI undergo cranial tomographic imaging within 22 minutes of arrival in the hospital (standard deviation [SD]: = 17 minutes).
- The in-hospital mortality of moderate to severe TBI is 23.5%. Nearly 60% of the patients make a good recovery or recover with only mild impairment by the time of discharge or transfer from the acute-care hospital.
- Lack of definitions and non-uniform standards of data acquisition make it difficult to compare data from Germany with data obtained in other countries; guidelines are needed for the standardization of definitions, inclusion criteria, study methods, and reporting with respect to the epidemiology of TBI in Germany and Europe.

- Rickels E, von Wild K, Wenzlaff P: Head injury in Germany: a population-based prospective study on epidemiology, causes, treatment and outcome of all degrees of head-injury severity in two distinct areas. *Brain Inj* 2010; 24: 1491–504.
- Steudel WI, Cortbus F, Schwerdtfeger K: Epidemiology and prevention of fatal head injuries in Germany: trends and the impact of reunification. *Acta Neurochir* 2005; 147: 231–42.
- Firsching R, Woischneck D: Present status of neurosurgical trauma in Germany. *World J Surg* 2001; 25: 1221–3.
- Maegele M, Engel D, Bouillon B, et al.: Incidence and outcome of traumatic brain injury in an urban area in Western Europe over 10 years. *Eur Surg Res* 2007; 39: 372–9.
- Fu TS, Jing R, Fu WW, Cusimano MD: Epidemiological trends of traumatic brain injury identified in the emergency department in a publicly-insured population, 2002–2010. *PLoS One* 2016; 11: e0145469.
- Majdan M, Plancikova D, Brazinova A, et al.: Epidemiology of traumatic brain injuries in Europe: A cross-sectional analysis. *Lancet Public Health* 2016; 1: e76–e83.
- TraumaRegister DGU®: 20 years TraumaRegister DGU®: Development, aims and structure. *Injury* 2014; 45 (Suppl 3): 6–13.
- Gennarelli A, Wodzin E (eds.): The Abbreviated Injury Scale 2005. Update 2008. American Association for Automotive Medicine (AAAM), Des Plaines, IL 2008.
- Foreman BP, Caesar RR, Parks J, et al.: Usefulness of the Abbreviated Injury Score and the Injury Severity Score in comparison to the Glasgow Coma Scale in predicting outcome after traumatic brain injury. *J Trauma* 2007; 62: 946–50.
- Wutzler S, Maegele M, Marzi I, et al.: Association of preexisting medical conditions with in-hospital mortality in multiple trauma. *Am Coll Surg* 2009; 209: 75–81.
- Maegele M, Schöchl H, Menovsky T, et al.: Coagulopathy and haemorrhagic progression in traumatic brain injury: advances in mechanisms, diagnosis and management. *Lancet Neurol* 2017; 16: 630–47.
- Firsching R, Rickels E, Mauer UM, et al.: Guidelines for the treatment of head injury in adults. *J Neurol Surg A Cent Eur Neurosurg* 2017; 78: 478–87.
- Maas AI, Harrison-Felix CL, Menon D, et al.: Standardizing data collection in traumatic brain injury. *J Neurotrauma* 2011; 28: 177–87.

Corresponding author

Prof. Dr. med. Marc Maegele
Klinik für Unfallchirurgie, Orthopädie und Sporttraumatologie
Kliniken der Stadt Köln-Merheim
Institut für Forschung in der Operativen Medizin (IFOM)
Universität Witten/Herdecke (Campus Köln-Merheim)
Ostmerheimer Str. 200, D-51109 Cologne, Germany
Marc.Maegele@t-online.de